

### Job Outlook

Employment of mathematicians is expected to decrease through 2008. The number of jobs available for workers whose educational background is solely in mathematics is not expected to increase significantly. Those whose educational background includes the study of a related discipline such as statistics or computer science will have better job opportunities. Advancements in technology usually lead to expanding applications of mathematics, and more workers with knowledge of mathematics will be required in the future. Many of these workers have job titles that reflect their occupation rather than the discipline of mathematics used in their work.

Bachelor's degree holders in mathematics are usually not qualified for most jobs as mathematicians. However, those with a strong background in computer science, electrical or mechanical engineering, or operations research should have good opportunities. In addition, bachelor's degree holders who meet State certification requirements may become high school mathematics teachers. (For additional information, see the statement on kindergarten, elementary, and secondary school teachers elsewhere in the *Handbook*.)

Holders of a master's degree in mathematics will face very strong competition for jobs in theoretical research. Similar to bachelor's degree holders, however, job opportunities in applied mathematics and related areas, such as computer programming, operations research, and engineering design will be more numerous. Academia continues to produce more Ph.D.s than the number of university positions available, so many of these mathematicians will need to find employment in industry and government.

### Earnings

Median annual earnings of mathematicians were \$49,120 in 1998. The middle 50 percent earned between \$33,420 and \$77,300. The lowest 10 percent had earnings of less than \$25,150, while the top 10 percent earned over \$101,990.

According to a 1999 survey by the National Association of Colleges and Employers, starting salary offers for mathematics graduates with a bachelor's degree averaged about \$37,300 a year and for those with a master's degree, \$42,000. Doctoral degree candidates averaged \$58,900. The average annual salary for mathematicians employed by the Federal Government in supervisory, nonsupervisory, and managerial positions was \$69,000; for mathematical statisticians, \$69,000; and for cryptanalysts, \$61,100 in early 1999.

### Related Occupations

Other occupations that require extensive knowledge of mathematics or, in some cases, a degree in mathematics include actuary, statistician, computer programmer, systems analyst, systems engineer, and operations research analyst. A strong background in mathematics also facilitates employment in engineering, economics, finance, and physics.

### Sources of Additional Information

For more information about careers and training in mathematics, especially for doctoral level employment, contact:

☛ American Mathematical Society, Department of Professional Programs and Services, P.O. Box 6248, Providence, RI 02940-6248.

Internet: <http://www.ams.org>

For more information about careers and training in mathematics, contact:

☛ Mathematical Association of America, 1529 18th St. NW., Washington, DC 20036. Internet: <http://www.maa.org>

For a 1998 resource guide on careers in mathematical sciences, contact:

☛ Conference Board of the Mathematical Sciences, 1529 18th St. NW., Washington, DC 20036. Internet: <http://www.maa.org/cbms/cbms.html>

For specific information on careers in applied mathematics, contact:

☛ Society for Industrial and Applied Mathematics, 3600 University City Science Center, Philadelphia, PA 19104-2688.

Internet: <http://www.siam.org/alterindex.htm>

Information on obtaining a job as a mathematician with the Federal Government may be obtained from the Office of Personnel Management through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (912) 757-3000; TDD (912) 744-2299. This number is not toll free and charges may result. Information may also be obtained through their Internet site: <http://www.usajobs.opm.gov>

## Operations Research Analysts

(O\*NET 25302)

### Significant Points

- Individuals with a master's or Ph.D. degree in management science, operations research, or a closely related field should have good job prospects.
- Employment growth is projected to be slower than average.

### Nature of the Work

Operations research (OR) and management science are terms that are used interchangeably to describe the discipline of applying quantitative techniques to make decisions and solve problems. Many methods used in operations research were developed during World War II to help take the guesswork out of missions such as deploying radar, searching for enemy submarines, and getting supplies where they were most needed. Following the war, numerous peacetime applications emerged, leading to the use of OR and management science in many industries and occupations.

The prevalence of operations research in the Nation's economy reflects the growing complexity of managing large organizations that require the efficient use of materials, equipment, and people. OR analysts determine the optimal means of coordinating these elements to achieve specified goals by applying mathematical principles to organizational problems. They solve problems in different ways and propose alternative solutions to management, which then chooses the course of action that best meets their goals. In general, OR analysts are concerned with issues such as strategy, forecasting, resource allocation, facilities layout, inventory control, personnel schedules, and distribution systems.

The duties of the operations research analyst vary according to the structure and management philosophy of the employer or client. Some firms centralize operations research in one department; others use operations research in each division. Some organizations contract operations research services with a consulting firm. Economists, systems analysts, mathematicians, industrial engineers, and others may apply operations research techniques to address problems in their respective fields. Operations research analysts may also work closely with senior managers to identify and solve a variety of problems.

Regardless of the type or structure of the client organization, operations research in its classical role of carrying out analysis to support management's quest for performance improvement entails a similar set of procedures. Managers begin the process by describing the symptoms of a problem to the analyst, who then formally defines the problem. For example, an operations research analyst for an auto manufacturer may be asked to determine the best inventory level for each of the parts needed on a production line and to determine the number of windshields to be kept in inventory. Too

many windshields would be wasteful and expensive, while too few could result in an unintended halt in production.

Operations research analysts study such problems, then break them into their component parts. Analysts then gather information about each of these parts from a variety of sources. To determine the most efficient amount of inventory to be kept on hand, for example, OR analysts might talk with engineers about production levels, discuss purchasing arrangements with buyers, and examine data on storage costs provided by the accounting department.

With this information in hand, the analyst is ready to select the most appropriate analytical technique. Analysts could use several techniques—including simulation, linear and non-linear optimization, networks, waiting lines, discrete and random variables methods, dynamic programming, queuing models and other stochastic-process models, Markov decision processes, econometric methods, data envelopment analysis, neural networks, genetic algorithms, decision analysis, and the analytic hierarchy process. All of these techniques, however, involve the construction of a mathematical model that attempts to describe the system in use. The use of models enables the analyst to assign values to the different components, and determine the relationships between them. These values can be altered to examine what will happen to the system under different circumstances.

In most cases, the computer program used to solve the model must be modified repeatedly to reflect these different solutions. A model for airline flight scheduling, for example, might include variables for the cities to be connected, amount of fuel required to fly the routes, projected levels of passenger demand, varying ticket and fuel prices, pilot scheduling, and maintenance costs. By choosing different variables for the model, the analyst is able to produce the best flight schedule consistent with various sets of assumptions.

Upon concluding the analysis, the operations research analyst presents management with recommendations based on the results of the analysis. Additional computer programming based on different assumptions may be needed to help select the best recommendation offered by the OR analyst. Once management reaches a decision, the analyst may work with others in the organization to ensure the plan's successful implementation.

### Working Conditions

Operations research analysts generally work regular hours in an office environment. Because they work on projects that are of immediate interest to top management, OR analysts often are under pressure to meet deadlines and work more than a 40-hour week.

### Employment

Operations research analysts held about 76,000 jobs in 1998. Major employers include telecommunication companies, air carriers, computer



*Operations research analysts use mathematical models to break down problems into their components before finding a solution.*

and data processing services, financial institutions, insurance carriers, engineering and management services firms, and the Federal Government. Most operations research analysts in the Federal Government work for the Armed Forces, and many OR analysts in private industry work directly or indirectly on national defense. About 1 out of 5 analysts work for management, research, public relations, and testing agencies that do operations research consulting.

### Training, Other Qualifications, and Advancement

Employers generally prefer applicants with at least a master's degree in operations research, engineering, business, mathematics, information systems, or management science, coupled with a bachelor's degree in computer science or a quantitative discipline such as economics, mathematics, or statistics. Dual graduate degrees in operations research and computer science are especially attractive to employers. Operations research analysts also must be able to think logically and work well with people, and employers prefer workers with good oral and written communication skills.

In addition to formal education, employers often sponsor training for experienced workers, helping them keep up with new developments in OR techniques and computer science. Some analysts attend advanced university classes on these subjects at their employer's expense.

Because computers are the most important tools for quantitative analysis, training and experience in programming are required. Operations research analysts typically need to be proficient in database collection and management, programming, and in the development and use of sophisticated software programs.

Beginning analysts usually perform routine work under the supervision of more experienced analysts. As they gain knowledge and experience, they are assigned more complex tasks and given greater autonomy to design models and solve problems. Operations research analysts advance by assuming positions as technical specialists or supervisors. The skills acquired by operations research analysts are useful for higher-level management jobs, and experienced analysts may leave the field to assume nontechnical managerial or administrative positions.

### Job Outlook

Individuals who hold a master's or Ph.D. degree in operations research, management science, or a closely related field should find good job opportunities through 2008, as the number of openings generated by employment growth and the need to replace those leaving the occupation is expected to exceed the number of persons graduating with these credentials. In addition, graduates with bachelor's degrees in operations research or management science from the limited number of schools offering these degree programs should find opportunities in a variety of related fields that allow them to use their quantitative abilities.

The slower than average employment growth expected for OR analysts will be driven by the continuing use of operations research and management science techniques to improve productivity, ensure quality, and reduce costs in private industry and government. This should result in a steady demand for workers knowledgeable in operations research techniques in the years ahead. Nevertheless, this growth will be relatively slow because few job openings in this field are expected to have the title operations research analyst.

### Earnings

Median annual earnings of OR analysts were \$49,070 in 1998. The middle 50 percent earned between \$36,890 and \$72,090. The lowest 10 percent had earnings of less than \$29,780, while the top 10 percent earned over \$87,720. Median annual earnings in the industries employing the largest number of OR analysts in 1997 are shown below.

Research and testing services .....	\$64,000
Computer and data processing services .....	45,400
Commercial banks .....	37,500

The average annual salary for operations research analysts in the Federal Government in nonsupervisory, supervisory, and managerial positions was \$72,000 in early 1999.

### Related Occupations

Operations research analysts apply mathematical principles to large, complicated problems. Workers in other occupations that stress quantitative analysis include computer scientists, systems analysts, modeling specialists, logistics consultants, engineers, mathematicians, statisticians, and economists. Because its goal is improved organizational effectiveness, operations research also is closely allied to managerial occupations.

### Sources of Additional Information

Information on career opportunities for operations research analysts is available from:

☛ The Institute for Operations Research and the Management Sciences, 901 Elkridge Landing Rd., Suite 400, Linthicum, MD 21090. Internet: <http://www.informs.org>

For information on OR careers in the Armed Forces and Department of Defense, contact:

☛ Military Operations Research Society, 101 South Whiting St., Suite 202, Alexandria, VA 22304. Internet: <http://www.mors.org>

## Statisticians

(O\*NET 25312)

### Significant Points

- Many individuals with degrees in statistics enter jobs that do not have the title statistician.
- Job prospects as a statistician in private industry and academia will be best for those with a graduate degree and some work experience in statistics.

### Nature of the Work

Statistics is the scientific application of mathematical principles to the collection, analysis and presentation of numerical data. Statisticians contribute to scientific inquiry by applying their mathematical knowledge to the design of surveys and experiments; collection, processing, and analysis of data; and interpretation of the results. Statisticians often apply their knowledge of statistical methods to a variety of subject areas, such as biology, economics, engineering, medicine, public health, psychology, marketing, and education. Many applications cannot occur without use of statistical techniques, such as designing experiments to gain Federal approval of a newly manufactured drug.

One especially useful technique used by statisticians is sampling—obtaining information about a population of people or group of things by surveying a small portion of the total. For example, to determine the size of the audience for particular programs, television-rating services survey only a few thousand families, rather than all viewers. Statisticians decide where and how to gather the data, determine the type and size of the sample group, and develop the survey questionnaire or reporting form. They also prepare instructions for workers who will collect and tabulate the data. Finally, statisticians analyze, interpret, and summarize the data using computer software.

In manufacturing industries, statisticians play an important role in quality control and product improvement. In an automobile company, for example, statisticians might design experiments to determine the failure time of engines exposed to extreme weather conditions by running individual engines until failure and breakdown. Such destructive tests are conducted on a representative sample of



*Statisticians need good communication skills to convey complex ideas to a nontechnical audience.*

the engines, and the results enable the company to identify changes that can improve engine performance.

Because statistical specialists are used in so many work areas, specialists who use statistics often have different professional designations. For example, a person using statistical methods on economic data may have the title econometrician, while statisticians in public health and medicine may hold titles of biostatistician, biometrician, or epidemiologist. (See the statement on economists and marketing research analysts elsewhere in the *Handbook*).

### Working Conditions

Statisticians usually work regular hours in comfortable offices. Some statisticians travel to provide advice on research projects, supervise and set up surveys, or gather statistical data. Some may have duties that vary widely, such as designing experiments or performing fieldwork in various communities. Statisticians who work in academia generally have a mix of teaching and research responsibilities.

### Employment

Persons holding the title of statistician held about 17,000 jobs in 1998. Over one-fourth of these jobs were in the Federal Government, where statisticians were concentrated in the Departments of Commerce, Agriculture, and Health and Human Services. Most of the remaining jobs were in private industry, especially in the biopharmaceutical industry. In addition, many professionals with a background in statistics were among the 20,000 mathematics faculty in colleges and universities in 1998, according to the American Mathematical Society. (See the statement on college and university faculty elsewhere in the *Handbook*.)

### Training, Other Qualifications, and Advancement

Although more employment opportunities are becoming available to well qualified statisticians with bachelor's degrees, a master's degree in statistics or mathematics is the minimum educational requirement for most jobs with job title statistician. Research positions in institutions of higher education, for example, require a graduate degree, usually a doctorate, in statistics. Beginning positions in industrial research often require a master's degree combined with several years of experience.

The training required for employment as an entry level statistician in the Federal Government, however, is a bachelor's degree, including at least 15 semester hours of statistics or a combination of 15 hours of mathematics and statistics, if at least 6 semester hours are in statistics. Qualifying as a mathematical statistician in the Federal Government requires 24 semester hours of mathematics and statistics with a minimum of 6 semester hours in statistics